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A Study on Slot Design of Motorcycle Windshield to Improve Aerodynamics Features

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Abstract

In motorcycle competitions, aerodynamics plays a fundamental role. In order to improve the performance of racing motorbikes, various windshield designs have been studied experimentally. The objective of this study was to minimize the magnitude of skin-friction on a Ducati 1198SP track-motorcycle's windshield via the integration of slots. An alpha prototype in the motorcycle windshield was designed for the Ducati 1198SP track-motorcycle, and validation was performed on the performance of the newly designed slot variation in the motorcycle windshield in term of aerodynamic features. The newly concept included a double layered windshield construction with the integration of slots, which was tested in a wind tunnel to compare its aerodynamics properties with a stock windshield design of the Ducati 1198SP track-motorcycle. It was proven via the experiment that the Concept I has successfully improved the aerodynamic performance when the tilted angle of the slotted design was at 3.9472°. The particular windshield had the lowest coefficient of drag, lift and the drag and lift force when it travels at 20 m/s. For future studies, more variations of the slot and double layer designs could be further tested.

Keywords

Motorcycle, windshield, aerodynamics, skin-friction, performance

Introduction

In motorcycle grand Prix, in order to increase performance, thus, elevating the chances to win a race; drag force is minimized by the reduction of skin-friction drag for the motorcycle. In reducing skin-friction drag, motorcycles have opted to the use of smooth and streamlined body-panels

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(fairing) and windshield since these approaches have been well documented to improve aerodynamics (Nuclear Power, 2018). The windshield functions to channel airflow and protecting the motorcyclist from road debris and insects flying towards motorcyclist (Ma'arof 2018). The wind has direct influence towards the rider as it is a laminar flow. If the windshield as poor streamlining, it will trap turbulence and therefore create higher pressure. By getting higher pressure, drag force in turn is bigger and there will create turbulent wake zone and reverse flow wherein laminar does not have such occurrence (Gratzer, L., 1986). In other words, poor aerodynamic is unwanted factor especially in racing motorcycle design. Aerodynamic design from windshield can either make the airflow to be streamlined or causing the airflow to be a turbulence flow.

Implementation of slot is verified to enhance aerodynamic of an airfoil on an airplane (Joseph, K., 1930). In recent study it had been shown that it had a rather contradictory outcome with respect to the inclusion of slot in motorcycle's windshield design. The particular study has indicated more studies are needed to be done to test the integration of various slot design on the motorcycle windshield in order to improve the aerodynamic of the vehicle (Tan, K. ,n.d). To put it briefly, motorcycle can travel faster with the aid of windshield. Slat and slot are commonly found in aircraft wings. Both are operated to increase the angle of attack at the aerodynamic surface of leading edge at the wing (Kelley-Wickemeyer, R., Seidel, G., Anast, P. and McLean, J. ,2001). Slat can be opened up to allow a gap (slot) between the slat and the wing for the air to pass through them (BikeBandit.com, 2018).

The goal of this study was to minimize the magnitude of skin-friction on a Ducati 1198SP track-motorcycle's windshield via the integration of slots. This goal was accomplished by achieving following research objectives: (i) to design an alpha prototype in the motorcycle windshield in improving the aerodynamics parameters for the Ducati 1198SP track-motorcycle, and (ii) to analyse and validate the performance on the newly designed slot variation in the motorcycle windshield in term of aerodynamic performance for the Ducati 1198SP track-motorcycle.

Methodology

Six experiments were conducted to identify the parameters such as Coefficient of Drag, C_D; Coefficient of Lift , C_L; Drag Force , F_x; and Lift Force , F_y starting from 10m/s (Experiment I) to the maximum speed of 30 m/s (Experiment VI) i.e. 5m/s increment per experiment. The experiments were conducted in an overall dimension of 8.8m length, 2.0m width and 2.3m in height of an Aeronautical Wind Tunnel which is a type of Low Speed Tunnel (LST) at University Teknologi MARA System Aeronautics Laboratory. It has a cross section of 0.5m x 0.5m of test section with maximum length of test section to be 1.25m. The contraction ratio for this wind tunnel is 9:1 and the maximum speed achievable is 30m/sec. The speed of fan blade is then varied from 10m/s to 30m/s with interval of 5m/s. From Data Acquisition System, the result obtained are Coefficient of Drag C_D, Coefficient of Lift C_L, Coefficient of Moment C_M, Drag Force F_x, Lift Force F_y, Moment M_z, Differential Pressure P_d, Temperature T_a and Air Density ρ. The fixed parameters on wind tunnel are ambient pressure, P_a and pitch angle on 0°. There are two models used for the experimentation purposes. Stock Design Windshield has fixed angle of attack whereas

Concept I has various angle of attack by changing the angle with $\theta_1, \theta_2, \theta_3, \theta_4, \theta_5$ on the top part layer to determine the optimum angle for the windshield. The Concept I used a double layered windshield construction with the integration of slots.

Figure 1. Experiment set up in a wind tunnel

Area (A) for rectangular shape in meter square unit (m^2):

$$A = Length \times Height \tag{1}$$

Area (A) for triangular shape in meter square unit (m^2):

$$A=\frac{1}{2} \times Length \times Height \tag{2}$$

Lift was calculated as: $L = N \cos\alpha + F \sin\alpha$ (3)

Where L = lift; N = normal force; α = angle of attack; F = force along chord line

Drag was calculated as: $D = N \sin\alpha + F \cos\alpha$ (4)

Where D = lift; N = normal force; α = angle of attack; F = force along chord line

Coefficient of Lift: $C_L = L/(q * S)$ (5)

Where C_L = coefficient of lift; L = lift; q = dynamic pressure; S = area

Coefficient of Drag: $C_D = D/(q * S)$ (6)

Where C_D = coefficient of drag; D = drag; q = dynamic pressure; S = area

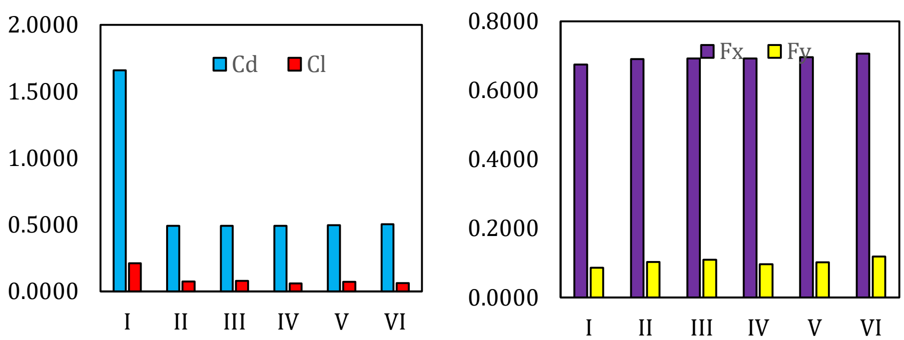
Area (A) for Stock Design Windshield was $0.00754\, m^2$ and Total Area (A) for Concept was $0.026124\, m^2$

Results and Discussion

As the speed increases with interval of 5 m/s, the C_D and C_L of all experiments decrease proportionally. Experiment I has the highest overall C_D and C_L throughout speed from 10 m/s to 30 m/s with the lowest value being 1.6596 for C_D when speed reaches 30 m/s and highest at 1.7532 for speed 10 m/s, whereas highest value for C_L is 0.2359 at 10 m/s and lowest around 0.2116 at 30 m/s. Overall, Experiment IV has the lowest C_D and C_L among the six experiment conducted for all the speed tested. In other words, when the motorcycle cruises during low speed and accelerates to 30 m/s, Concept I windshield with θ_3 = 3.9472° angle has the lowest coefficient of lift and drag. The lower the coefficient of lift and drag, the better the ability of a motorcycle to accelerate in a straight line and takes lower time to achieve maximum speed.

As for drag force F_x and Lift Force F_y for all experiments conducted, it can be observed both F_x and F_y have highest value at two different types of windshield analysis. During low speed from 10 m/s until 20m/s, Experiment III with angle of windshield θ_2 = 2.6337° has the highest value of 0.3161kgf for F_x and 0.0409kgf for F_y. During high speed travel, Experiment VI with angle of windshield θ_5 = 6.5602° has highest value of F_x and F_y that stands on maximum of 0.7058kgf and 0.1182kgf respectively at the speed of 30 m/s. When the windshield travels at different speed at a time, it can be regarded that throughout low speed, each windshield has the lowest value of F_x and F_y as Experiment VI, I and IV during speed of 10 m/s, 20 m/s and 30 m/s from the tabulated data at section 4.4. However, when speed reaches 25 m/s to 30 m/s, Stock Design Windshield has the lowest F_x and F_y among the tests conducted. A value of 0.4744 kgf and 0.0589 kgf for both F_x and F_y are the lowest during high speed for Experiment I. Values obtained for F_x and F_y means the drag force and lift force generated when motorcycle travels at certain speed. As Ducati 1198SP constantly travels at high speed, it is taken into consideration that Experiment I with windshield from stock motorcycle suits the criteria as it generates the least F_x and F_y.

Figure 2.0 Graph of C_D and C_L and F_x and F_y at Speed 30 m/s



Nonetheless, it is ideal for the windshield to fulfil all the parameters with the lowest values possible in term of coefficient of lift, coefficient of drag, lift force and drag force. By obtaining all the values, Concept I windshield with angle θ_3 = 3.9472° are selected as the best among all other windshields because it does fulfil the prerequisite of lowest value possible obtained when the motorcycle travels at the speed of 20 m/s. Concept I windshield with angle θ_3 = 3.9472° is chosen in preference to all the experiments conducted as during a racing competition, an one second lead or trail makes the difference between placing the first or second.

Conclusions

The goal of this study was to minimize the magnitude of skin-friction on a Ducati 1198SP track-motorcycle's windshield via the integration of slots. This study is a pioneering research in the integration of slot design into windshield. It is an initiation in bringing new innovation to the windshield industry by applying a double layered with slot design into a windshield. The effects of any of the listed parameters in this project is unknown as each of the parameters may result in getting different outcome if one is being manipulated. The performance of newly designed slot variation was compared to the stock windshield design from the motorcycle. It is proven that with slotted design of windshield the aerodynamic performance of the motorcycle increased when the tilted angle of the slotted design was at 3.9472°. It can be observed from the data obtained through wind tunnel experiments that the aforementioned windshield has the lowest coefficient of drag, lift and the drag and lift force is at the lowest when it travels at 20 m/s. By having the lowest C_D and C_L tested among the other five experiments, the airflow of the upper part of the motorcycle is improved. For future studies, more variations of the slot and double layer designs could be further tested.

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